Spatial distribution of acceptor-related recombination centers in Mg-doped GaN

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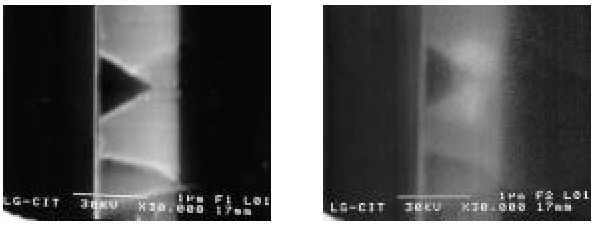
Despite the high performance of recently commercialized blue LED and LD[1], many of detailed characteristics of III-nitrides have not been fully understood yet. In particular, high activation energy of Mg-related acceptors keeps a low resistive *p*-GaN layer from being routinely grown. Therefore, the optical and electrical properties of *p*-GaN have been reported to vary significantly depending on the samples under investigation. In fact, the some characteristics of optical luminescence of *p*-GaN are still under controversy. It has been known that there are two dominant transitions observed near at 2.8 eV and 3.2 eV[4-5]. For highly Mg doped GaN layers, quenching of transitions at 3.2 eV was claimed to be initiated by several different sources such as Mg-H complex, increased deep donor levels involved in self-compensation, disordering, defect complex and Mg interstitial[2-5]. In this work, we found spatial variation of dissimilar emissions and aimed at finding the origins of the variation of Mg-related acceptor activation centers in conjunction with defects employing cathodoluminescence (CL). We also investigated the extent of quenching of 3.2 eV transition depending on doping concentrations.

As for Mg-doped GaN samples, typical CL peaks of emission are located at about 2.8 eV and 3.2 eV even though the exact peak positions depend on the excitation power. In Fig. 1, secondary electron image and monochromatic CL images taken at 2.8 eV and 3.2 eV are shown for the sample of which lateral growth is not completed. Monochromatic CL image taken at 3.2 eV is observed to be bright around the crystalline defects where lateral merging is not complete. In contrast, CL image at 2.8 eV emission shows uniform distribution of luminescence except the crystalline defect area. In consistent with the plan view CL image, cross-sectional CL image shows a similar trend of luminescence distribution as shown in Fig.2. We measured RT CL spectra of Mg-doped GaN as a function of doping concentration and its result is shown in Fig.3. When Mg concentration is less than $1.5 \times 10^{19} cm^{-3}$,emission peak is observed approximately at 3.2 eV. When Mg concentration in the range of $1.5 \sim 5 \times 10^{19}$ cm^{-3}, both shallow and deep acceptor level at 3.2 eV and 2.8 eV are observed, respectively. In the heavily doped samples with Mg at a minimum level of 5×10^{19} cm^{-3}, the CL spectra are dominated by transitions centered at about 2.8 eV.

Usually in case of highly doped GaN:Mg which has good crystal quality, the emission peak at 2.8 eV alone is observed. For further investigation, we also measured depth profile of CL spectra. To exclude absorption effect of high energy emission at surface region by low energy emission band, the measurement was carried out with the film thinned gradually. The 3.2 eV emission was not observed at the top surface, but began to appear as the film was thinned by dry etching as shown in Fig.4. Thus, it is likely that the emission peak around 3.2 eV is not completely quenched out for heavily doped GaN, but exists near the interface region. As mentioned before this remained 3.2 eV emission peak is mainly related to the crystalline defects which are typically generated at the initial stage growth. The cross sectional CL spectra shows that the 2.8 eV emission is distributed in the top region and 3.2eV emission is in the region of interface. The result provides an evidence that more Mg atoms associated with 2.8 eV emission are activated near the surface regime. We can conclude, from the monochromatic CL image, that the 3.2 eV emission band seems to originate from the region where many crystalline defects which are in general formed at the initial stage of growth. And from the result of CL spectra for dry etched sample, we could know that the 3.2 eV emission band is not fully quenched out even for highly compensated GaN:Mg.

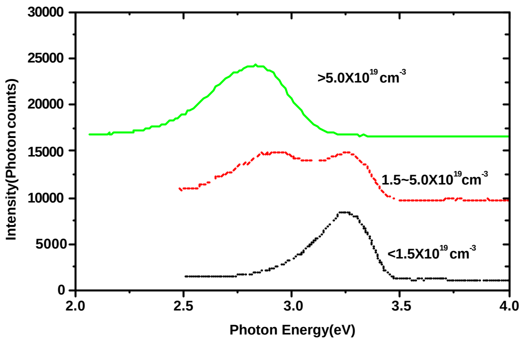
(a) (b) (c)

Fig.1 SEM image (a), CL image at 3.2eV (b), and CL image at 2.8eV (c) around the region of crystalline defect



(a) (b)

Fig.2 SEM image (a), and monochromatic CL image at 3.2eV of the cross section of GaN:Mg



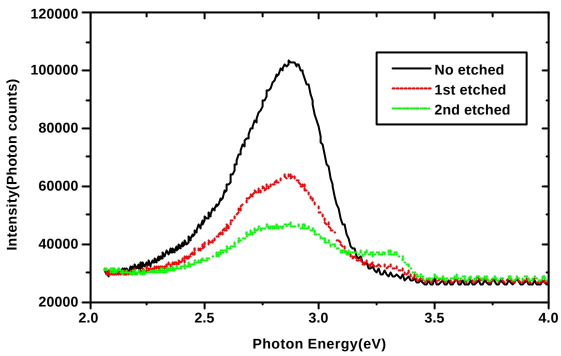


Fig.3 CL spectra dependence on Mg concentration

Fig.4 Depth profile of CL spectra

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